Tibiofemoral Joint Contact Area and Pressure After Single- and Double-Bundle Anterior Cruciate Ligament Reconstruction

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Purpose: The purpose of this study was to compare the tibiofemoral contact area and pressure after single-bundle (SB) and double-bundle (DB) anterior cruciate ligament (ACL) reconstruction by use of 2 femoral and 2 tibial tunnels in intact cadaveric knees. **Methods:** Tibiofemoral contact area and mean and maximum pressures were measured by pressure-sensitive film (Fujifilm, Valhalla, NY) inserted between the tibia and femur. The knee was subjected to a 1,000-N axial load by use of a uniaxial testing machine at 0°, 15°, 30°, and 45° of flexion. Three conditions were evaluated: (1) intact ACL, (2) SB ACL reconstruction (n = 10 knees), and (3) DB ACL reconstruction (n = 9 knees). **Results:** When compared with the intact knee, DB ACL reconstruction showed no significant difference in tibiofemoral contact area and mean and maximum pressures. SB ACL reconstruction had a significantly smaller contact area on the lateral and medial tibiofemoral joints at 30° and 15° of flexion. SB ACL reconstruction also had significantly higher mean pressures at 15° of flexion on the medial tibiofemoral joint and at 0° and 15° of flexion on the lateral tibiofemoral joint, as well as significantly higher maximum pressures at 15° of flexion on the lateral tibiofemoral joint. **Conclusions:** SB ACL reconstruction resulted in a significantly smaller tibiofemoral contact area and higher pressures. DB ACL more closely restores the normal contact area and pressure mainly at low flexion angles. **Clinical Relevance:** Our findings suggest that the changes in the contact area and pressures after SB ACL reconstruction may be one of the causes of osteoarthritis on long-term follow-up. DB ACL reconstruction may reduce the incidence of osteoarthritis by closely restoring contact area and pressure. **Key Words:** Anterior cruciate ligament reconstruction—Double bundle—Tibiofemoral—Contact pressure—Contact area.

Anterior cruciate ligament (ACL) injury is the most common knee injury related to sports activities. In the United States alone, there are approximately 100,000 ACL tears each year.[1] Single-bundle (SB) ACL reconstruction is the most commonly performed surgical procedure for ACL injury. However, a recent meta-analysis by Biau et al.[2] has shown that only 60% of patients treated with a traditional SB reconstruction were satisfied with their outcome. Degenerative radiographic changes are seen in 82% to 89% of the patients at long-term follow-up.[3,4] Despite this high incidence of osteoarthritis, little is known about the changes in tibiofemoral contact area and pressure after ACL reconstruction.

The ACL is composed of 2 functional bundles, the anteromedial (AM) bundle[5] and the posterolateral (PL) bundle.[6] Traditional SB ACL reconstruction mostly resembles the reconstruction of the AM bundle, which restores the anterior-posterior knee stability during dynamic loading.[7] The PL bundle is also important for anterior tibial translation because there is

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an increase in anterior tibial translation, under a pivot-shift force, in the PL bundle–deficient knee, and this bundle is important for the control of rotational stability at 0° and 30° of knee flexion.[8]

The abnormal tibial rotation found at 2 years after SB ACL reconstruction has been shown to be similar to that of ACL-deficient knees.[9] It has been suggested that this excessive internal tibial rotation may be associated with the degenerative cartilage changes in ACL-deficient and ACL-reconstructed patients.[9,10] Biomechanical studies in cadavers have shown that anatomic double-bundle (DB) ACL reconstruction provides not only better anterior-posterior stability but also better rotational stability as compared with conventional SB ACL reconstruction.[11,12] Despite the biomechanical advantages of DB ACL reconstruction, the outcome studies have not been long enough to show whether this technique decreases the incidence of osteoarthritis.

To investigate possible reasons for the high incidence of osteoarthritis after SB ACL reconstruction and the potential advantages of DB ACL reconstruction, this study compared the tibiofemoral joint contact area and pressure after SB and DB ACL reconstruction with those of intact knees. It is hypothesized that (1) SB ACL reconstruction will result in a decrease in tibiofemoral joint contact area and increase in pressure as compared with those of intact knees and (2) DB ACL reconstruction will more closely restore the normal tibiofemoral joint contact area and pressure when compared with SB ACL reconstruction.

METHODS

Specimen Preparation

Twenty-two fresh-frozen human cadaveric knees (LifeLegacy Foundation, Tucson, AZ) were used in this study. Anteroposterior and lateral radiographs were obtained for each knee to assess signs of osteoarthritis. Specimens were stored at −20°C pending testing and thawed overnight at room temperature. The semitendinosus and gracilis tendons were harvested and wrapped in saline solution–soaked gauze. The fibula was fixed to the tibia with a screw to maintain its anatomic position. The proximal and distal segments of each specimen were dissected to expose more than 10 cm of bone. The specimens were subsequently potted within custom-made aluminum cylinders by use of an epoxy compound (Bond-Tite Products, Cleveland, OH) and placed in the testing machine by use of custom fixtures. Three cadaveric knees were excluded from the study: one had knee dislocation and two had tibial plateau fractures during testing. The remaining 19 cadavers (age range, 27 to 78 years; mean age, 46.7 ± 16.5 years) were divided into 2 groups: the SB ACL reconstruction group (n = 10) and the DB ACL reconstruction group (n = 9). The knees from both groups were first tested with the ACL intact, followed by ACL transection and arthroscopic SB or DB ACL reconstruction. Testing was again performed after the reconstruction surgery.

Testing System

An axial testing machine (Adelaide Testing Machines, Toronto, Ontario, Canada) was used to apply 1,000 N of axial load to the tibia in the direction of the tibial longitudinal axis. Once the specimen was placed in the machine, the required flexion angle was adjusted by moving the femur on the coronal plane; the desired knee flexion was locked in position by the machine. The tibia was allowed to move freely in 3 *df* (anterior-posterior, medial-lateral, and internal rotation–external rotation) under loading. The pressure measurement films (Fuji Prescale Film; Fujifilm, Valhalla, NY) were cut into a semicircular shape to be fit into the medial and lateral tibiofemoral joint space below the menisci and were overlapped and enclosed with plastic wrap and sealed with tape (Fig 1). Super low–pressure films (pressure range, 0.5 to 2.5 MPa) were used to measure the tibiofemoral contact area, and low-pressure films (pressure range, 2.5 to 10 MPa) were used to measure the tibiofemoral pressure.

For both films, calibration was done before testing by applying several known stresses to the film and noting the color intensity. Linear interpolation was used to calculate stress values between the calibration values based on the color intensity. The films were scanned, and the contact area was calculated by measuring the area (pixels) with any shade of red coloring. The maximum press is given by the pixel with the greatest color intensity and is converted to a pressure by use of the calibration curve. The mean pressure is obtained by averaging the pressures of the pixels. The calculations were assisted by use of the MATLAB software program (The MathWorks, Natick, MA).

Surgical Techniques

After testing the intact ACL condition, we immediately performed surgery. All procedures were performed arthroscopically. The ACL of each knee was removed with a shaver and endoscopic punch. No meniscal injury was identified in any specimen.